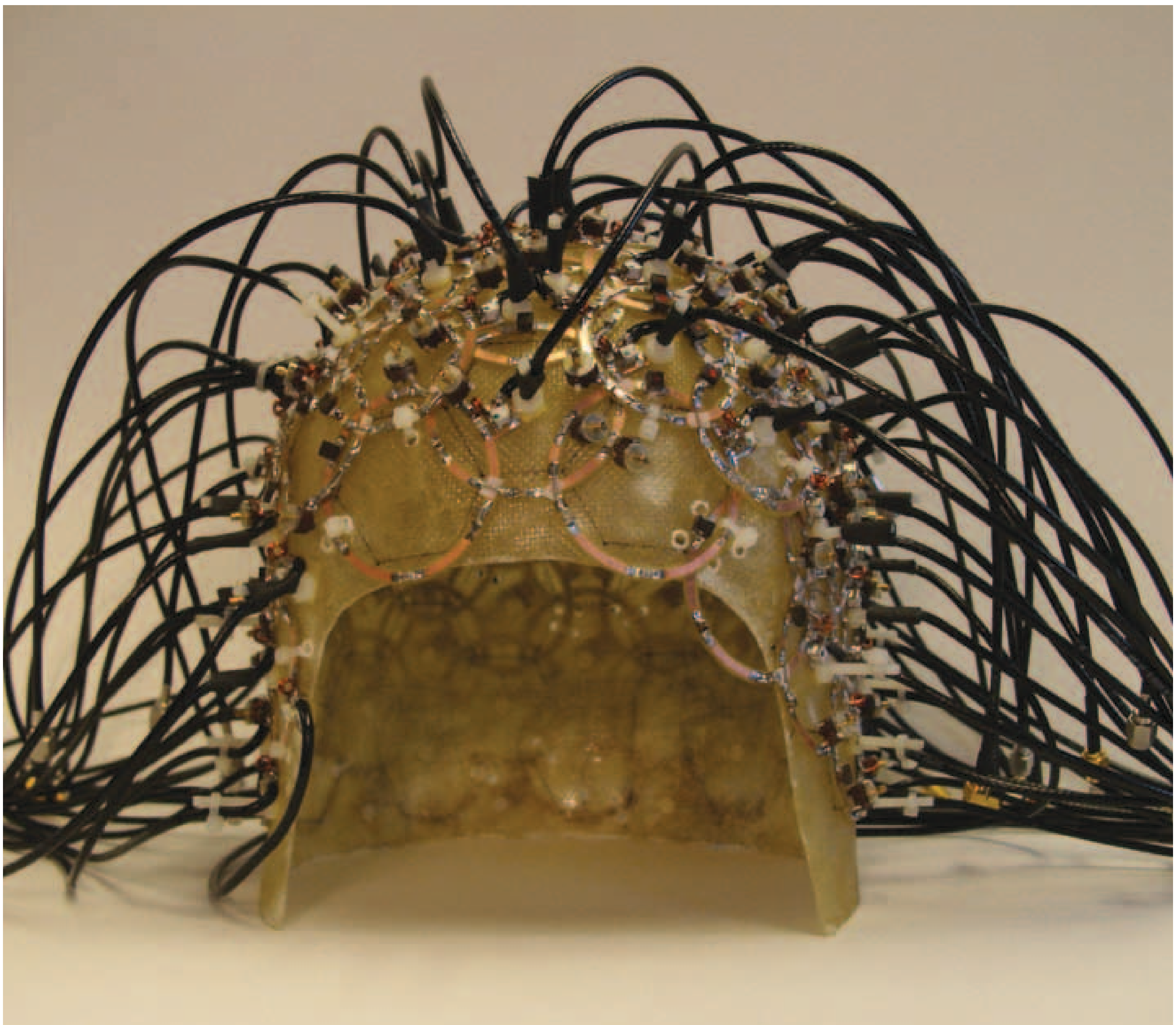
Examining the Brain's Fine Structure

Few experiences at the doctor's office cause more frustration than hearing "we've completed all the tests, but we still don't know what's causing your disorder." For a person with epilepsy, the frustration is understandable. If doctors can find a lesion in the patient's brain, surgeons might be able to remove it, offering the possibility of full recovery. But if nothing abnormal shows up on the brain scans, the patient is left to suffer seizures and follow drug regimens that are sometimes ineffective and produce unwanted side effects.

Now these patients have new hope, thanks to research at the Center for Functional Imaging Technologies at Massachusetts General Hospital (MGH), an NCRR-supported Biomedical



■ A prototype helmet bears 90 overlapping coils that pick up an MRI signal. The helmet, designed by NCRR-supported researchers at Massachusetts General Hospital, defied scientific dogma to make more powerful brain scans possible.

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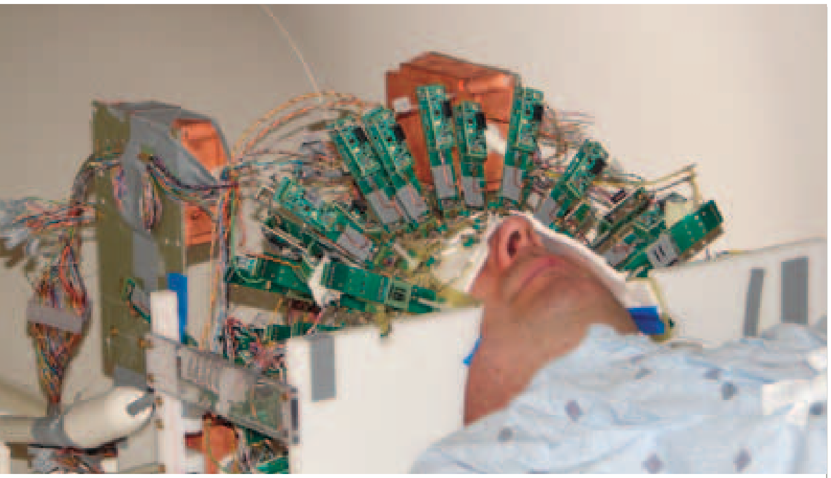

■ A subject wearing the experimental multi-coil helmet is ready to slide into the MRI magnet. Green preamplifiers radiate from each MRI signal detector on the helmet. The preamplifiers magnify the detected electronic signals and send them to a digitizer and a computer, which reconstructs and combines the data to form the final high-resolution image of the subject's brain.

Technology Research Center (BTRC). These researchers have created an MRI brain-scanning instrument so powerful that it can pick up the tiniest of lesions, even those as small as a blood vessel. The instrument uses dozens of overlapping coils that pick up the MRI signal, all built into a helmet that fits closely to the patient's head.

The Center for Functional Imaging Technologies is one of more than 50 NCRR-funded BTRCs across the United States that enable researchers to develop and distribute new technologies and methodologies. At MGH, the center allowed researchers to realize a clinically important technique and make a discovery that challenged scientific norms.

"The thought was that it wouldn't really work," said Bruce R. Rosen, principal investigator of the center. Previously, scientists thought that small coils could provide images only of tissue near the coil, not deep within an organ like the brain. NCRR funding enabled the researchers to build prototype coils and purchase high-field magnets to test their idea. The result? "The established dogma wasn't right," Rosen said. Instead, the coils worked together to produce high-resolution images throughout the brain.

The image resolution was more than double that of images obtained using standard techniques. Such a jump would previously have required doubling the strength of the magnet, a multimillion-dollar expense. Rosen added that the multi-coil helmet allows much faster imaging of the brain at a fraction of the cost.

When the researchers combined the helmet with a higher-power magnet, the two technologies aligned surprisingly well. "They're made for each other," Rosen said. Resolution increased nearly 10-fold in some parts of the brain. NCRR also supported the MGH team's development of the computational tools to analyze data from the scans.

The MGH team published its results on a 32-coil design in the journal *Magnetic Resonance in Medicine* in 2006. A manuscript about a 96-coil design was published in July 2009 in the same journal.

Already, the technology company Siemens has collaborated with MGH to commercialize a helmet based on the new design, using 32 coils and a 3-Tesla magnet. Meanwhile, the researchers have pushed their design to 128 coils and used it with more powerful magnets. The MGH team's experimental helmet looks a bit like medieval armor with wires attached, whereas the commercial version of the helmet looks like something a stormtrooper might wear in *Star Wars*.

"We are seeing things we just weren't able to see before — things like very small brain tumors or lesions that cause epileptic seizures," Rosen said.

The move from experimental technology to commercialized product has been rapid, and Rosen envisions continued progress in providing patients with access to the new scanners. "I would guess that in the not-too-distant future, these will become ubiquitous," he said.

"They're making a major step to move high-resolution imaging to the clinic for diagnostics and treatment," said Abraham Levy of NCRR's Division of Biomedical Technology. "You can use the MGH technology to study schizophrenia, Alzheimer's disease and all kinds of other disorders that relate to the brain." With NCRR support, Rosen and his colleagues continue to investigate the optimal number of coils. They also hope to develop a multi-coil instrument to use with children. Because children are unable to hold still for very long, they often have to undergo anesthesia to get an MRI scan. If the extra coils can make the scanning process faster, they might enable MRI without anesthesia even for small children.

For a doctor or technician, administering an MRI using the coil-encrusted helmet is not that different from providing a traditional MRI scan of the brain: both involve placing a head wrap on the patient and then sliding him or her into a large, doughnut-shaped magnet.

"The patient experience is essentially identical to the way it was before," Rosen said. "However, now there is a stronger potential for a diagnosis that can lead to a more effective treatment and, ideally, a long-lasting, life-altering impact." ■

—LILA GUTERMAN

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